a) how fast is the space station moving if it is in uniform circular motion around the Earth?


$F_c = F_g = mg$

$$\boxed{ma = \frac{GMm}{r^2}}$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$r = r_E + h$

$$g = \frac{GM}{r^2} = a$$

$$\frac{v^2}{\cancel{r}} = \frac{GM}{r^{\cancel{2}}} = \frac{6.67\times10^{-11}\frac{Nm^2}{kg^2}(5.98\times10^{24}kg)}{(6.38\times10^6 + 400\,000m)}$$

$$v = \sqrt{58829793} = \boxed{7.67\times10^3 m/s}$$

b) what is the period of revolution?

$$\frac{4\pi^2 r}{T^2} = \frac{GM}{r^2} = 8.68\ m/s^2$$

$(6.78\times10^6 m)^3$

$$T^2 = \frac{4\pi^2 r^3}{GM} = \frac{4\pi^2}{6.67\times10^{-11}(5.98\times10^{24})}$$

$(\quad)^3$

$6.67\times10^{-11}(5.98\times10^{24})$

$T^2 = (30847629.8)$

$T = 5.55\times10^3 s = \boxed{1.54 hrs}$

c) how far away are geostationary satellites?

$T = 24 hrs$ over the equator

$\boxed{F_g = F_c}$ orbits big idea

$\frac{GMm}{r^2} = \frac{m 4\pi^2 r}{T^2}$ $(24hr\times3600s/h)^2$

$r^3 = \frac{GMT^2}{4\pi^2} = \frac{6.67\times10^{-11}(5.98\times10^{24})}{4\pi^2}$

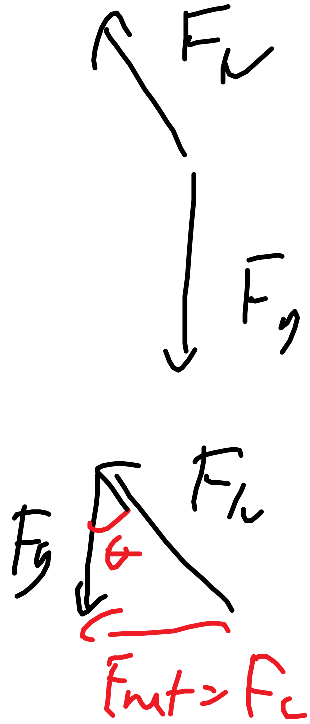
$r = \sqrt[3]{7.542\times10^{22}} = 4.23\times10^7 m$

$h=r-r_E = 4.23\times10^7m-6.38\times10^6m = 3.59 \times 10^7m$

Wow, that's pretty far.

p122 Q 21-33  lab report

Q 15


$$\tan\theta = \frac{F_{net}}{F_g} = \frac{\cancel{m}a}{\cancel{m}g}$$

$$\tan\theta = \frac{v^2}{rg}$$ ← Perfectly banked

$v = 60\,km/h = 16.67\,m/s$

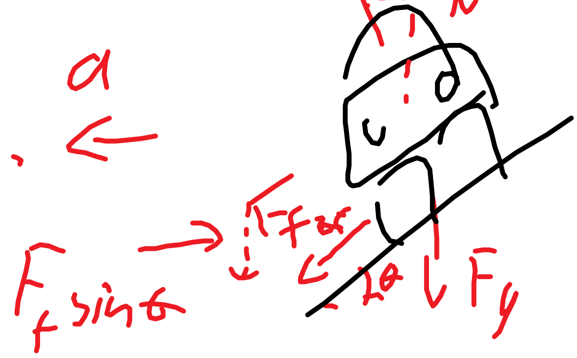
$r = 60\,m$

$$\theta = \tan^{-1}\left(\frac{(16.67\,m/s)^2}{60\,m \times 9.80\,m/s^2}\right)$$

$$\boxed{\theta = 25.20^\circ}$$

if $v > 60\,km/h$, $F_f$

∴ $F_N$ increase as u increases




$F_f = \mu F_N$

down forces

$$F_g + \mu F_N \sin\theta = F_N \cos\theta$$

left

$$m\frac{v^2}{r} = F_N \sin\theta + \mu F_N \cos\theta$$

1. The international space station is 400 km above the surface of the Earth, on average.

a) determine g at that height.

* Big Iden $F_g = mg = \frac{GMm}{r^2}$

orbit $\boxed{F_g = F_c}$ * $\boxed{g = a}$

$$\frac{6.67\times10^{-11}(5.98\times10^{24})}{(6.38\times10^{6}m + 400\,000m)^2} = \boxed{8.67\,\frac{N}{kg}}$$

d) how fast is the space station moving if it is in uniform circular motion around the Earth?

$$F_c = F_g$$

$$\frac{\cancel{m} v^2}{\cancel{r}} = \frac{G M \cancel{m}}{r^{\cancel{2}}} =$$

$$v^2 = \frac{(6.67\times10^{-11}\,\frac{Nm^2}{kg^2})(5.98\times10^{24}\,kg)}{(6.38\times10^6\,m + 400\,000\,m)} =$$

$$\boxed{v = 7.67\times10^3\ m/s}$$

d) what is the period of revolution?

$$F_c = F_g$$

$$\cancel{m}\frac{4\pi^2 r}{T^2} = \frac{G M \cancel{m}}{r^2}$$

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

$$T^2 = \frac{4\pi^2 (6.78\times10^6\,m)^3}{\ldots}$$

$$T^2 = \frac{4\pi^2 (6.\ldots)}{6.67\times10^{-11}(5.98\times10^{24})}$$

$$T^2 = 3084762 9.8 \quad T = 5.55\times10^4 s$$

$$T\left(5.55\times10^4 s \times \frac{1h}{3600s}\right) = \boxed{1.54 hrs}$$

e) how far away are geostationary satellites?

$$F_g = F_c \quad T = 24 hrs$$

$$\frac{GM\cancel{m}}{r^2} = \frac{\cancel{m}4\pi^2 r}{T^2}$$

$$y = 10^x$$

$$r^3 = \frac{GMT^2}{4\pi^2} \qquad \log y = x$$

$$r^3 = \frac{6.67\times10^{-11}(5.98\times10^{24})(24\times3600)^2}{4\pi^2} \qquad \log 10 = 1 \qquad \log 100 = 2$$

$$r = \sqrt[3]{7.542\times10^{22}} = 4.225\times10^7 m$$

$$h = r - r_E = \boxed{3.59\times10^7 m}$$

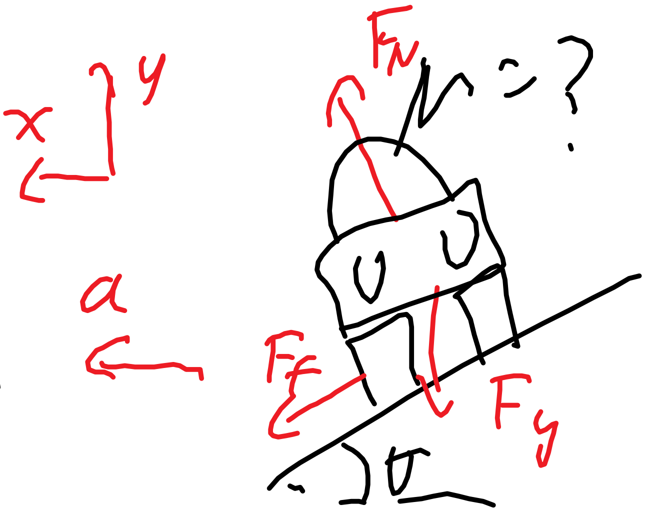
p122 Q 21-33 lab report

p119

Q15 Banked for 60 km/hr

$\theta = ?$

$\mu = ?$ if $v = 90$ km/h





$$\tan\theta = \frac{F_c}{F_y} = \frac{\cancel{m}a}{\cancel{m}g}$$

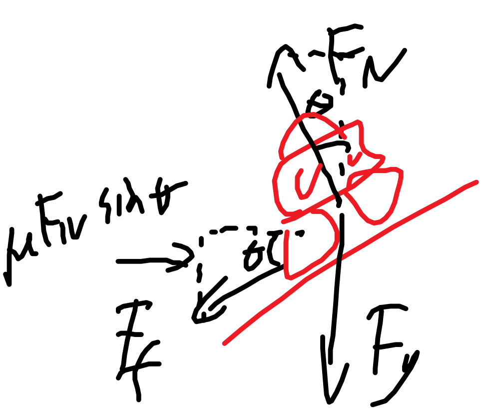
$60\ \text{km/h} = 16.67$

$$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\frac{(16.67\ \text{m/s})^2}{60\ \text{m}\,(9.8\ \text{m/s}^2)}$$

$$\theta = 25.29^\circ$$

$\Sigma F_y = 0 \quad \Sigma F_x = ma = \frac{mv^2}{r}$




up

down

$$F_N \cos\theta = F_g + \mu F_N \sin\theta$$

$$F_f = \mu F_N$$

$$m\frac{v^2}{r} = \mu F_N \cos\theta + F_N \sin\theta$$

sub in, solve for $F_N$
and cancel it out
solve for $\mu$.

eg. the international space station is 400km away from the Earth, radius $6.38 \times 10^6$m and mass $5.98 \times 10^{24}$kg. What is

a) g at the space station
b) Fg on a 70 kg astronaut.
c) why does the astronaut feel weightless?
d) how fast is the space station moving if it is in uniform circular motion around the Earth?

Big Idea * $F_g = F_c$ orbits

$$\cancel{m}g = \cancel{m}\frac{v^2}{r}$$

$$\frac{GM}{r^{\cancel{2}}} = \frac{v^2}{\cancel{r}}$$

$$v^2 = \frac{(6.67\times10^{-11})(5.98\times10^{24})}{(\underbrace{6.38\times10^{6}}_{r_E} + \underbrace{400\,000}_{h\ \text{km}})}$$

$$\boxed{v = 7.7\times10^{3}\ \text{m/s}}$$

e) what is the period of revolution?

$$F_c = F_g$$

$$\frac{\cancel{m}4\pi^2 r}{T^2} = \frac{GM\cancel{m}}{r^2}$$

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

$$T^2 = \frac{4\pi^2(6.78\times10^{6})^3}{6.67\times10^{-11}(5.98\times10^{24})}$$

$$T^2 = 30847629.8$$

$$T = 5554.15\left(\frac{1h}{3600s}\right) =$$

$$\boxed{1.54\ \text{hrs}}$$

a) how far away are geostationary satellites?

$$g = \frac{GM}{r^2}$$

$$\frac{g_p}{g_E} = \frac{\cancel{G} M_p / \cancel{r_p^2}}{\cancel{G} M_E / \cancel{r_E^2}} = \frac{M_p}{M_E}$$

e) $T = 24\,hrs$ $\quad F_g = F_c$

$$\frac{GM\cancel{m}}{r^2} = \frac{\cancel{m} 4\pi^2 r}{T^2}$$

$$r^3 = \frac{GMT^2}{4\pi^2}$$

$$r^3 = \frac{6.67\times10^{-11}(5.98\times10^{24})\left(24\,hrs \times \frac{3600\,s}{h}\right)}{4\pi^2}$$

$$r^3 = (7.542\times10^{22}\,m^3)$$

$$r = \sqrt[3]{7.542\times10^{22}} = \underline{4.23\times10^{7}\,m}$$

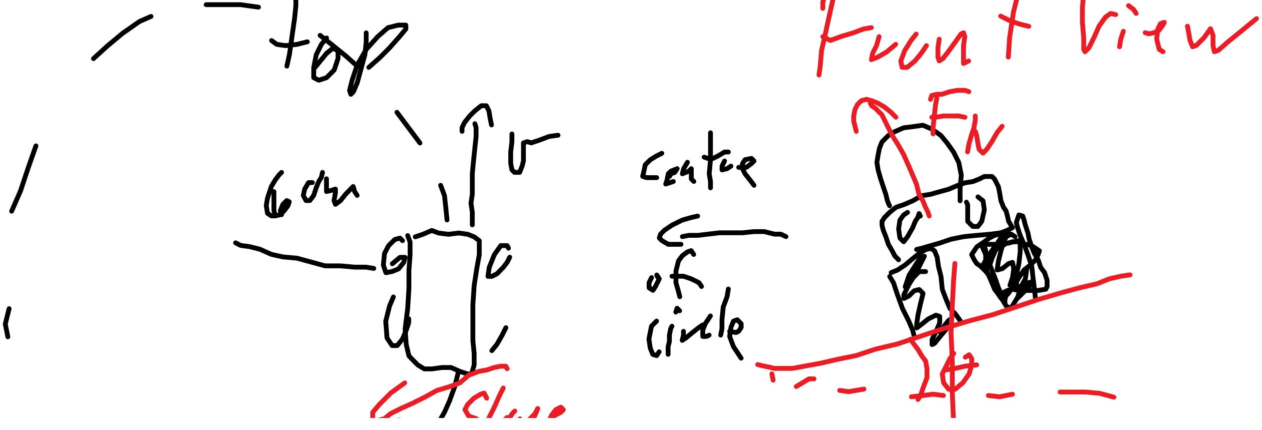
$$h = r - r_E = \boxed{3.59\times10^{7}\,m}$$

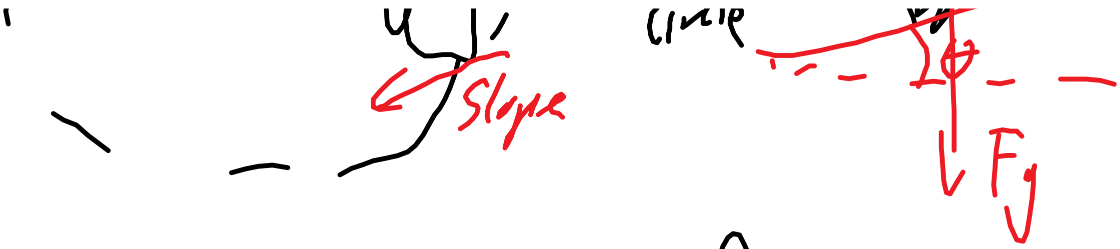
p119 Q15

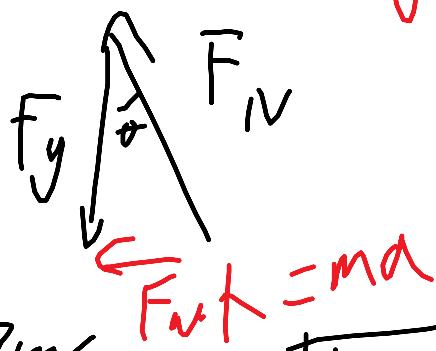
road is banked for a car moving at 60km/hr with a radius of 60m

a) what is the banking angle?

b) (tricky) what coefficient of friction is required to keep the car from sliding up the hill if it goes 90 km/hr?





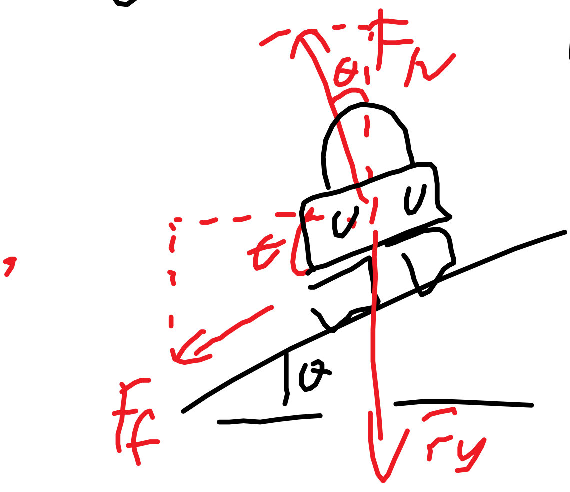




$$\tan\theta = \frac{\cancel{m}a}{\cancel{m}g}$$

$60\,km/h = 16.67\,m/s$

$$\boxed{\tan\theta = \frac{v^2}{rg}}$$

$$\theta = \tan^{-1}\frac{(16.67\,m/s)^2}{60\,m\,(9.8\,m/s^2)} = \boxed{25.3^\circ}$$




$F_f = \mu F_N$

$\sum F_y = 0 \qquad \sum F_x = ma$

up

down

$F_N\cos\theta = F_g + \mu F_N\sin\theta$

$\sum F_x = ma = \mu F_N\cos\theta + F_N\sin\theta$

p 122

Q 27 $\qquad r = ? \qquad g = \frac{1}{25} g_E$

$$g = \frac{GM}{r^2} \qquad \frac{\cancel{G}\cancel{M}}{r^2} = \frac{1}{25}\frac{\cancel{G}\cancel{M}}{r_E^2}$$

$$g = \frac{GM}{r^2} \qquad \frac{GM}{r^2} = \frac{1}{25}\frac{GM}{r_E^2}$$

$$25 r_E^2 = r^2$$

$$\boxed{r = 5 r_E}$$